

SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

February 16, 2000
NSRP 0559
N7-96-7

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Auto Feed Stud Gun for Insulation Pins

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

in cooperation with
Halter Marine Group, Inc.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE 16 FEB 2000		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE The National Shipbuilding Research Program, Auto Feed Stud Gun for Insulation Pins				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230-Design Integration Tower Bldg 192, Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5000				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 31	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

DISCLAIMER

These reports were prepared as an account of government-sponsored work. Neither the United States, nor the United States Navy, nor any person acting on behalf of the United States Navy (A) makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness or usefulness of the information contained in this report/manual, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or (B) assumes any liabilities with respect to the use of or for damages resulting from the use of any information, apparatus, method, or process disclosed in the report. As used in the above, "Persons acting on behalf of the United States Navy" includes any employee, contractor, or subcontractor to the contractor of the United States Navy to the extent that such employee, contractor, or subcontractor to the contractor prepares, handles, or distributes, or provides access to any information pursuant to his employment or contract or subcontract to the contractor with the United States Navy. ANY POSSIBLE IMPLIED WARRANTIES OF MERCHANTABILITY AND/OR FITNESS FOR PURPOSE ARE SPECIFICALLY DISCLAIMED.

National Shipbuilding Research Project

#7-96-7

Milestone #12

Final Report

Prepared by
William C. Easterday
TRW Nelson Stud Welding Division
7900 West Ridge Road
Elyria, OH 44036-2019

February 16, 2000

NSRP #7-96-7 Final Report

A. ABSTRACT	4
A.1. PROJECT OBJECTIVE.....	4
A.2. BENEFITS.....	4
A.3. APPROACH.....	4
B. FIELD TEST OVERVIEW	5
B.1. FIELD TEST SITES –.....	5
B.1.1. NEWPORT NEWS SHIPBUILDING, NEWPORT NEWS VA.....	5
B.1.2. INGALLS SHIPBUILDING, PASCAGOULA MS	5
B.1.3. BATH IRON WORKS, BATH ME.....	5
B.1.4. ELECTRIC BOAT CORP., GROTON CT	5
B.2. MATERIALS PROVIDED –	5
B.3. FIELD TEST REPORTS –.....	5
C. EQUIPMENT FIELD TEST RESULTS	6
C.1. WELDING GUN	6
C.1.1. SIZE –.....	6
C.1.2. WEIGHT –.....	6
C.1.3. WELD SPACING –	7
C.1.4. DUTY CYCLE –	7
C.1.5. STUD LOADING –	7
C.1.6. STUD SUPPLY MAGAZINE –	8
C.1.7. BEARINGS –	8
C.1.8. SPARK SHIELD AND FOOT –.....	8
C.1.9. ORIENTATION –.....	9
C.1.10. GENERAL –.....	10
C.2. WELDING POWER UNIT –	10
C.2.1. SIZE AND WEIGHT –.....	10
C.2.2. STUD SIZE CAPACITY –.....	10
C.2.3. CONTROLS –.....	11
C.2.4. OPERATING VOLTAGE –	11
C.3. INSULATION PINS	11
C.3.1. LENGTH –	11
C.3.2. DIAMETER –	11
C.3.3. MATERIAL –	11
C.3.4. FEEDING METHOD –	12
C.3.5. QUANTITY –.....	12
C.4. GUN ADJUSTMENT AND OPERATION	12
C.4.1. STUD SIZE CHANGEOVER –	12
C.4.2. WELDING –.....	13
D. ACTIONS TAKEN.....	14
D.1. WELDING GUN	14
D.1.1. SIZE -	14
D.1.2. WEIGHT -.....	16
D.1.3. WELD SPACING -	17
D.1.4. DUTY CYCLE -	17
D.1.5. STUD LOADING.....	18
D.1.6. STUD SUPPLY MAGAZINE	20
D.1.7. BEARINGS.....	20
D.1.8. SPARK SHIELD AND FOOT.....	21
D.1.9. ORIENTATION.....	21

NSRP #7-96-7 Final Report

D.2.	WELDING POWER UNIT	21
D.2.1.	SIZE AND WEIGHT -	21
D.2.2.	STUD SIZE CAPACITY -	21
D.2.3.	CONTROLS -	21
D.2.4.	OPERATING VOLTAGE -	22
D.3.	INSULATION PINS	22
D.3.1.	LENGTH -	22
D.3.2.	DIAMETER -	22
D.3.3.	MATERIAL -	22
D.3.4.	FEEDING METHOD	23
D.3.5.	QUANTITY -	23
D.4.	GUN ADJUSTMENT AND OPERATION	24
D.4.1.	STUD SIZE CHANGEOVER -	24
D.4.2.	WELDING -	26
E.	APPENDIX	27

NSRP #7-96-7 Final Report

A. Abstract

A.1. Project Objective

- A.1.1. Develop a commercially viable lightweight stud welding gun with auxiliary apparatus suitable for use in a shipbuilding environment to automatically feed insulation pins and weld them in all positions with the short cycle process using either appropriate existing power/control units or a newly designed specific purpose power supply.

A.2. Benefits

- A.2.1. The results of this project will significantly increase the application speed of insulation pins thus reducing direct labor cost. Eliminating the need to manually load studs will reduce injuries and improve worker morale. All of these improvements will lead to increased reliability in the operation.

A.3. Approach

- A.3.1. This gun design includes a new stud feeding mechanism design based on mechanical simplicity, straightforward operation, adaptability to multiple stud lengths, and the elimination of unnecessary energy sources, sequencers, and their associated cabling.
- A.3.2. A new stud configuration was developed by Nelson Stud Welding specifically for use with this feeding system.
- A.3.3. The stud feeding mechanism design was laid out using AutoCAD release 14. After several iterations and simplifications, the final design was reviewed with Nelson Stud Welding Division's Marketing and Engineering staff. Some changes and improvements suggested by SP7 members prior to field testing were also incorporated.
- A.3.4. The gun, feeding mechanism, and power unit system was sent consecutively to four U.S. shipyards for evaluation. The results of this testing are presented as Section C of this *"Final Report."*
- A.3.5. Actions taken in response to suggestions made by the field test sites appear as Section D. This represents the gun and feeding mechanism as delivered to the NSRP MARITECH ASE Welding Technology Panel.
- A.3.6. A small, light weight inverter stud welding power supply has been developed independently by Nelson Stud Welding and is used with this system.

NSRP #7-96-7 Final Report

B. Field Test Overview

B.1. Field Test Sites –

Four sites were selected with the assistance of Lance Lemcool, Welding Technology Panel Program Manager. This particular combination of shipyards was chosen to provide a wide variety of possible Navy ship insulation retention applications. The initial schedule allowed for approximately one month per test site. Three weeks of actual testing and one week in transit were planned for each site.

B.1.1. Newport News Shipbuilding, Newport News VA

B.1.1.1. Planned duration - July 21, 1999 through August 11, 1999

B.1.1.2. Actual duration - July 23, 1999 through August 6, 1999

B.1.2. Ingalls Shipbuilding, Pascagoula MS

B.1.2.1. Planned duration - August 18, 1999 through September 8, 1999

B.1.2.2. Actual duration - August 20, 1999 through September 27, 1999

B.1.3. Bath Iron Works, Bath ME

B.1.3.1. Planned duration - September 15, 1999 through October 6, 1999

B.1.3.2. Actual duration - October 6, 1999 through November 12, 1999

B.1.4. Electric Boat Corp., Groton CT

B.1.4.1. Planned duration - October 13, 1999 through November 3, 1999

B.1.4.2. Actual duration - December 1, 1999 through December 15, 1999

B.2. Materials Provided –

In addition to the Nelson® ArcLite™ power unit, a cable set, and the stud welding gun with feed attachments, each test site was provided with a quantity of pre-filled stud cartridges and a video tape illustrating system operation, stud length change over, and maintenance procedures.

B.3. Field Test Reports –

Field test reports were solicited from each shipyard participating in this project. These appear in the appendices of the Milestone #8 document *"Report on Field Trial Tests"* in their entirety.

NSRP #7-96-7 Final Report

C. Equipment Field Test Results

This section of the final report is a review of the Milestone #8 document "*Report on Field Trial Tests.*" It is provided again here for reference.

C.1. Welding Gun

C.1.1. Size –

The gun design was believed to be as small and lightweight as practical without sacrificing ruggedness or efficiency. A novel new method of shortening the gun mechanism travel requirement and thus its overall length was developed by Nelson Stud Welding and was incorporated into this prototype. A reduction in overall gun length of approximately 3" (75mm) over a prior approach was realized. The gun's overall length as tested is approximately 14½" (370mm) when adjusted for welding studs used with 1" (25mm) nominal insulation thickness.

C.1.1.1. Testing at Ingalls Shipbuilding indicated that for their purposes this gun and stud feeding system will fit into about 70% of their locations where insulation pins are used in one application and 60% in another in its current state.

C.1.1.2. Bath Iron Works found that this gun, which is about 45% longer than the 10" (250mm) length of a hand loaded Soyer or Nelson® light duty gun, could reach many, but not all locations where these studs are applied.

C.1.1.3. The overall length of the gun with feeding mechanism would also limit the number of potential applications at Electric Boat Corporation.

C.1.1.4. No negative response about gun size was received from Newport News. It is presumed that the vast majority of their insulation pin stud requirements within the range capability of this feeding mechanism can be accommodated.

C.1.2. Weight –

Including 4 feet (1.2m) each of control and weld cables but without studs the gun weighed approximately 9 pounds (4.1kg) as field tested.

C.1.2.1. Newport News suggested that overhead welding with this gun may become awkward or uncomfortable if done for long periods.

C.1.2.2. Welding personnel at Bath Iron found the weight of this gun to be objectionable, particularly in comparison to a light duty hand feed Soyer or Nelson gun at about 4½ lbs. (2 kg). A limited number of

NSRP #7-96-7 Final Report

welders were willing to try the Nelson gun in production and only for a short time. BIW suggestions for weight reduction or improved ergonomics included:

C.1.2.2.1. Reorient the weld and control cables as they come out of the bottom of the gun handle.

C.1.2.2.2. Reduce thickness of the gun handle.

C.1.2.2.3. Use of lighter weight materials for the gun and feeding mechanism.

C.1.2.2.4. Use of smaller weld cable.

C.1.3. Weld Spacing –

The welding gun and its stud feeding mechanism are capable of welding studs on a 12" (300mm) square grid and within 3" (75mm) of a side wall. This was confirmed at Nelson Stud Welding Division's Elyria, Ohio facility prior to its submission to field testing.

C.1.4. Duty Cycle –

Stud application rate may be up to 30 studs per minute, limited by operator dexterity.

C.1.4.1. Newport News confirmed by a timed test that the gun and feeding mechanism are capable of meeting this requirement.

C.1.4.2. Bath Iron Works performed a side by side application rate comparison with a hand fed Soyer PS-0M light duty gun welding only six studs. The application rate ratio in this short test was 6:5 Nelson vs. Soyer.

C.1.5. Stud Loading –

A manual sliding action for the loading of studs to the chuck is provided.

C.1.5.1. While no problem was experienced during testing at Newport News Shipbuilding, a concern was expressed about the potential for arcing between the spring plunger knob and exposed surfaces of a ship. This test site suggested that a insulating cover be installed on the knob to prevent contact with metal parts of the hull.

C.1.5.2. Newport News reported that binding of the sliding mechanism can be induced if a user imparts a twisting motion by moving the upper slider by use of the end of the operating handle. Imparting this force closer to the gun centerline eliminates the binding. NNS suggested a somewhat shorter operating handle as a method of remedying this.

NSRP #7-96-7 Final Report

C.1.5.3. A commercial standard spring plunger is used to latch the upper slider of the stud feeding mechanism in the forward position for welding. Newport News Shipbuilding reported that they broke one of these during their field test. It was thought at that time that this may have been a byproduct of the binding mentioned above and the excessively hard cocking that it encouraged.

C.1.5.4. Bath Iron Works expressed a desire for a method of stud loading that allows one hand operation leaving one of the operator's hands free at all times. This would also allow for the removal of the side support handle and the handle on the stud loading mechanism.

C.1.5.5. Electric Boat observed that the loading mechanism operated smoothly for placing subsequent studs into the chuck for welding.

C.1.6. Stud Supply Magazine –

A spring loaded mechanical magazine and stud supply cartridge are used.

C.1.7. Bearings –

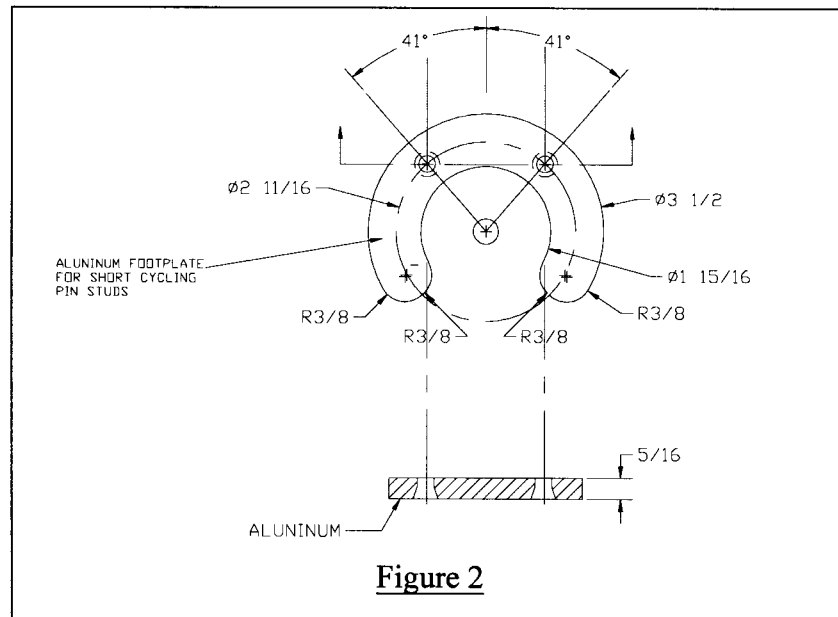
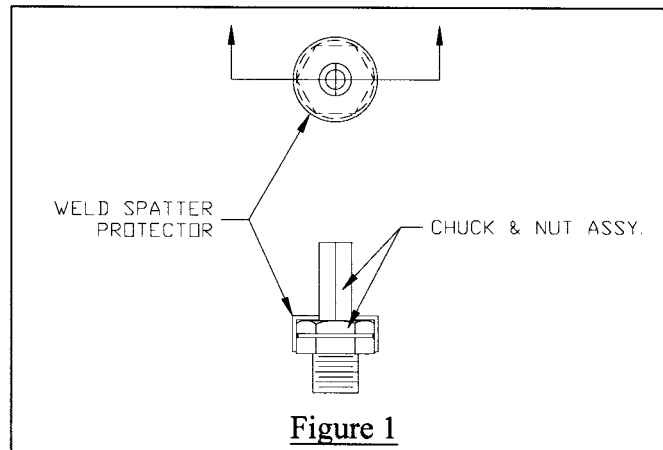
The distance between the linear bearing surfaces of the gun mechanism had been maximized to provide for accurate stud placement and to minimize the potential for binding.

C.1.8. Spark Shield and Foot –

An electrically insulating foot with adjustable bipod screws was provided for the mounting of a Stored-Arc®/Short Cycle style spark shield. The bipod screws, in conjunction with the spark shield, provide three points of contact with the work surface.

C.1.8.1. Newport News indicated that weld spatter buildup may be a problem particularly when welding short studs overhead. Use of an open horseshoe shaped foot plate, larger diameter spark shield, and/or spatter protection for the stud feeding mechanism were suggested. This foot plate approach may also reduce operator fatigue when welding overhead by simplifying the task of maintaining the stud perpendicular to the work surface. Refer to figures 1 and 2.

NSRP #7-96-7 Final Report



C.1.8.2. Bath Iron Works also expressed a concern about spatter buildup and erosion of the spark shield. The solution proposed by BIW is a copper or copper alloy outer tube with a ceramic liner. This is a spark shield design similar to those used by Nelson Stud Welding systems when applying the studs used for boiler relining in the electric utility industry.

C.1.9. Orientation –

The gun and stud feeding mechanism are capable of welding and feeding side hand, overhead, and down hand without modification.

NSRP #7-96-7 Final Report

C.1.9.1. The only apparent orientation issues pertained to gun weight and weld spatter when welding to overhead locations and are discussed separately above.

C.1.10. General –

The welding gun uses Nelson Stud Welding Division's field proven solenoid lifting coil and floating lift mechanism with hardened steel hook, lifting ring, and lifting rod sleeve.

C.2. Welding Power Unit –

The ArcLite™ power unit was developed independent of this project by Nelson Stud Welding. It is based on state of the art high frequency inverter technology and microprocessor control which provides for small size, light weight, and extremely rapid closed loop response to fluctuations in weld current.

C.2.1. Size and Weight –

13-3/16" x 9-1/4" x 22-7/8", 40 lbs. (335mm x 235mm x 580mm, 18kg)
All four shipyards were impressed with the small size, light weight, and current capacity of this power source.

C.2.2. Stud Size Capacity –

Using the drawn arc process, this unit is capable of welding up to a 1/2" (12mm) threaded stud with a pitch diameter base, Nelson CPL studs or equivalent. Duty cycle is generally inversely related to welding time and current requirements. In this particular short cycle pin welding application, at least 30 welds per minute are possible.

C.2.2.1. Ingalls and Newport News both successfully welded mild steel 3/8" (9.5mm) diameter studs with this power unit in the drawn arc mode.

C.2.2.2. Bath Iron Works welded mild steel 3/8-16 CPL ($\approx 8.4\text{mm}$ weld base) studs both with and without a 50 foot (15m) #1 AWG (43mm^2) copper extension cable. BIW also successfully welded 1/2-13 CPL studs ($\approx 11.4\text{mm}$ weld base) of both stainless steel and mild steel with the gun plugged directly into the ArcLite™ power unit. Bath noted that its stud diameter capacity compared favorably with that of the Nelson Series 4500 power unit at well under one-third the weight.

C.2.2.3. Newport News reported that although the ArcLite™ can handle many of their stud welding applications in its current form, a unit capable of welding full base 5/8" (16mm) diameter studs would handle virtually all of their stud welding requirements. The development of such a welding power supply is not considered a part of this project.

NSRP #7-96-7 Final Report

C.2.3. Controls –

Newport News suggested the addition of a weld time and current meter function. They also suggested that a protective cover for the front panel controls be available particularly for the environment onboard ships.

C.2.4. Operating Voltage –

This power unit had not yet been factory tested at voltages higher than 480 volts. All shipyards involved in the testing confirmed that this voltage would not be exceeded. Newport News went to the extent of running it from a portable line voltage regulator set at 465 volts. Production versions are planned for operation on 480 volts nominal with commercial line voltage tolerances of $\pm 10\%$.

C.3. Insulation Pins

C.3.1. Length –

Suitable for use with 1" (25mm), 1-1/2" (38mm), and 2" (50mm) nominal insulation thickness.

C.3.1.1. A length variation of approximately 1/8" (3mm) was found in one cartridge of studs for 2" (50mm) nominal insulation at Newport News.

C.3.2. Diameter –

0.177" (4.5mm) nominal with annular rings per MIL-S-24149 Type 6, Class 3, modified. Specifically tailored to the requirements of magazine or cartridge feeding. Fully compatible with Nelson Stud Welding part number 101-304-021 and other standard Navy Caps.

C.3.2.1. Bath Iron Works suggested that only one end of the studs have annular rings and that they extend down the body for only the length dictated by the MIL specs. BIW also recommended that a visual indication be provided of which orientation the resulting stud cartridges must be installed in.

C.3.2.2. Electric Boat Corporation suggested providing studs with no annular rings for their use.

C.3.3. Material –

Mild steel. Prototype studs were manufactured using C-1018 steel bar stock. This material was centerless ground to size, blanks were cut to length on a screw machine, and the annular rings were formed on a manually loaded thread roller using special dies.

C.3.3.1. A copy of the mill certification of material chemistry and tensile strength tests were requested from Nelson Stud Welding Division by both Bath Iron Works and Electric Boat. Tensile tests on a small

NSRP #7-96-7 Final Report

sample of the finished studs were also performed by Nelson Stud to confirm that the mill tensile results appeared to be correct. These documents appear in the Appendixes of the Milestone #8 document *"Report on Field Trial Tests."*

C.3.4. Feeding Method –

Disposable opaque PVC cartridges preloaded with studs.

C.3.5. Quantity –

Thirty studs per cartridge.

C.4. Gun Adjustment and Operation

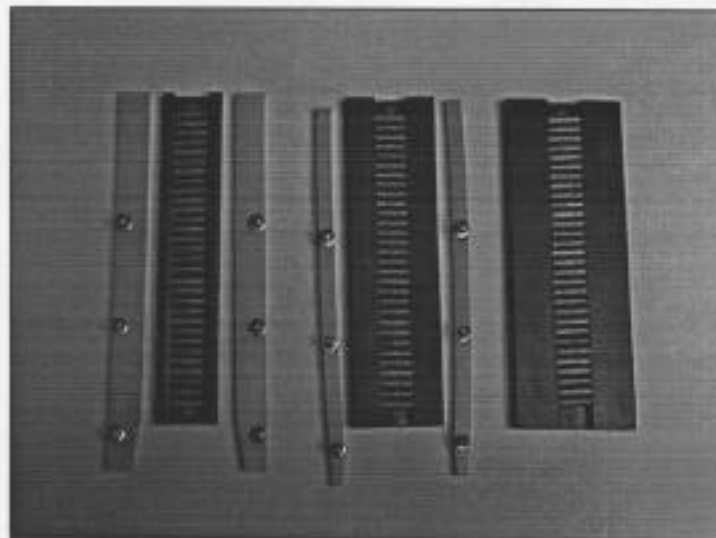
C.4.1. Stud Size Changeover –

C.4.1.1. The use of relatively small hardware for mounting the interchangeable aperture plates and magazine spacers in a shipyard environment was felt to be a potential problem by Newport News Shipbuilding, Bath Iron Works, and Electric Boat Corporation.

C.4.1.1.1. NNS recommended that the aperture plates, spacers, and their mounting hardware be incorporated into an interchangeable magazine design.

C.4.1.1.2. BIW suggested that a method of inserting cartridges for the shorter studs inside of cartridges for longer studs be developed.

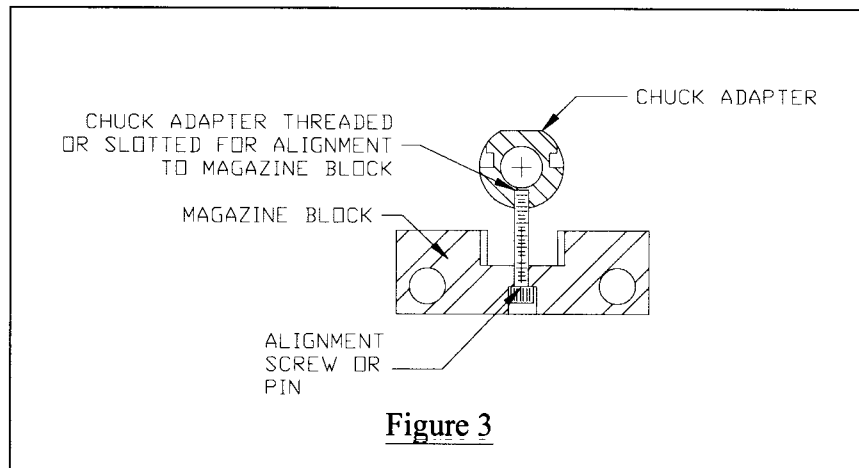
C.4.1.1.3. Electric Boat suggested that all cartridges have the same external dimensions to eliminate the need for removable spacers in the magazine and their associated mounting hardware. These spacers were used to take up the extra space in the magazine when studs shorter than the longest 1.94" ones are used.



NSRP #7-96-7 Final Report

C.4.1.2. It was determined at both Ingalls and Newport News that the angle between the bottom of the chuck adaptor and the top of the aperture plate must be maintained with a fair degree of accuracy to allow studs to reliably make this transition. NNS and the designer agreed that a funnel entry to the bottom of the aperture plate from the magazine and to the bottom of the chuck adaptor from the aperture plate would reduce or eliminate this problem.

C.4.1.3. Newport News suggested the use of a screw or pin as a chuck adaptor alignment aid during stud size change over. See figure 3.



C.4.1.4. Bath Iron suggested that all removable parts be located using pins to reduce the need for aligning individual parts when changing stud lengths.

C.4.2. Welding –

This welding tool operates like any hand held stud welding gun. The operator presses the spark shield against the work surface until the plunge has been taken up by the internal mechanism of the gun. A press of the trigger on the gun handle initiates the welding cycle. Once the weld is completed and the molten metal has cooled, the gun can be removed from the welded stud.

C.4.2.1. The process of removing the gun from a welded stud might be enhanced with the Newport News horseshoe shaped foot mentioned above.

NSRP #7-96-7 Final Report

D. Actions Taken

This section describes the actions taken to address the issues raised during field testing. The item numbering here generally matches, item for item, that of Section C *"Equipment Field Test Results."* For more information on these points, please refer to the comments in the previous section on which they are based.

Field test reports appear in the appendices of the Milestone #8 document *"Report on Field Trial Tests"* in their entirety.

D.1. Welding Gun

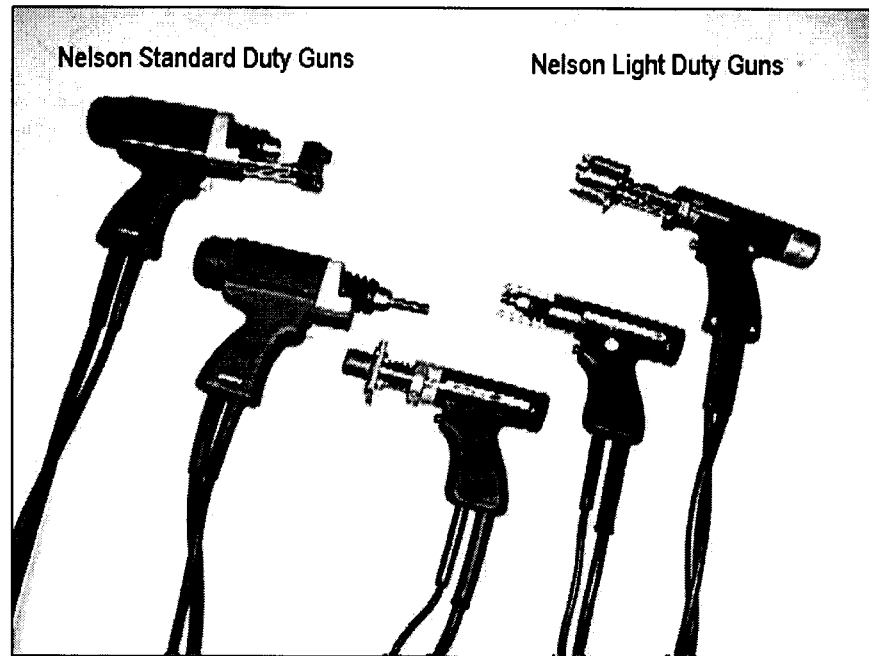
D.1.1. Size -

Bath Iron Works suggested that basing this system on a light duty Soyer or Nelson gun rather than Nelson's standard duty design would reduce its length significantly.



NSRP #7-96-7 Final Report

- D.1.1.1. A side by side comparison of Nelson's standard and light duty guns reveals that there is not a significant length difference between the two. This photograph shows several of these Nelson Stud Welding guns in both standard and light duty designs. Although light duty guns are slightly shorter than the gun of this project, their length would be approximately the same once a stud feeding mechanism were installed.



- D.1.1.2. A design that places multiple studs end to end in the chuck adaptor allowed reducing the travel of the stud loading mechanism slide. This in turn resulted in a chuck adaptor approximately 3" (75mm) shorter than would otherwise have been required. The gun as field tested incorporated this feature.
- D.1.1.3. The approach to shortening the gun in the previous item requires a floating lift gun mechanism to obtain consistent weld results. This mechanism allows for normal manufacturing tolerances on stud length without having an impact on arc length during the weld sequence. Arc length could vary by as much as $\pm 0.045"$ (1.2mm) or a total of about $3/32"$ (2.4mm) if this stud feeding mechanism were used with a fixed travel gun. The Nelson light duty gun is not currently available in a floating lift design which precludes its use at this time.

NSRP #7-96-7 Final Report

- D.1.1.4. The Soyer PS-0M proposed by Bath Iron also appears to be a fixed travel rather than a floating lift stud welding tool.



- D.1.1.5. Without a floating lift gun mechanism and the means of shortening the gun described above, the feeding mechanism would be about 3 inches (75mm) longer than what went out to the field for testing. A similar increase in travel of the human operated stud loading mechanism would also be needed.
- D.1.1.6. Since the overall length of a light duty gun with a feeding mechanism could actually be longer than the prototype as would the stroke required to load a stud to the chuck, Nelson Stud Welding plans to continue use of its standard gun as a basis for this design.

D.1.2. Weight -

Several measures were explored to further reduce the weight of the welding gun with feeding accessories installed.

- D.1.2.1. The weld cable was replaced with one fabricated from 4 AWG (20.6mm^2) rather than 2 AWG (33.6mm^2) welding cable for the part connected to the welding gun. For the 4 feet (1.2m) normally supported by an operator, this provides a weight reduction of about $4\frac{1}{2}$ ounces (125g). Usually, only this portion of the cable is supported by a person welding studs.

NSRP #7-96-7 Final Report

D.1.2.2. The phenolic foot with bipod pins was replaced with an aluminum, horseshoe shaped foot in accordance with a spatter buildup reduction suggestion from Newport News Shipbuilding. This change provided a coincidental weight savings of nearly 4 ounces (100g).

D.1.2.3. Unneeded material had already been removed from the rear coil yoke in the gun as originally field tested. This provided a weight savings of over 2 ounces (60g) over the standard Nelson NS-40 rear coil yoke.

D.1.2.4. Nelson Stud Welding implemented measures specifically targeted at weight saving as shown in this table. Some minor secondary weight savings resulted from elimination of the nylon filler bars in the magazine.

Item	Old Weight		New Weight		Weight Savings	
	lb	oz	lb	oz	lb	oz
Rear Coil Yoke		6.4		4.3		2.1
Stroke Limiter		0.1				0.1
Foot & Spark Shield		5.3		1.6		3.7
Weld Cable	2	10.7	1	12.8	1.0	(2.1)
Spring Plunger Insulator				0.1		(0.1)
Total	2	22.5	1	18.8	1.0	3.7
Decimal Pounds		3.41		2.18		1.23
kilograms		1.55		0.99		0.56

D.1.2.5. After these weight reduction measures, the welding gun with stud feeding attachments but without studs weighs approximately 7.2 pounds (3.2kg) including the 4 feet (1.2m) of cable that is typically supported by an operator. This compares favorably with its original 9 pound (4.1kg) weight.

D.1.3. Weld Spacing -

Stud to stud and stud to bulkhead spacing is well within the original design parameters. No corrective action was required for this item.

D.1.4. Duty Cycle -

The Nelson standard duty floating lift mechanism was found to be adequate for the duty cycle experienced during both lab and field testing.

D.1.4.1. The stud application rate determined by a timed test at Newport News Shipbuilding was found to meet the proposed rate of 30 welds per minute. The reduction in the potential for feeding mechanism binding that resulted by the use of a shorter upper slider operating handle should help maintain this rate in production.

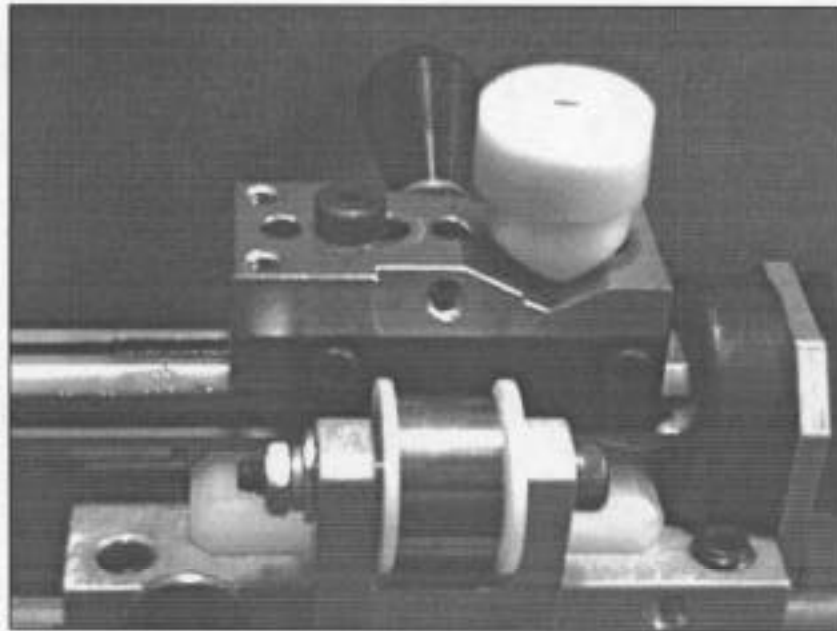
NSRP #7-96-7 Final Report

D.1.4.2. One shipyard had proposed basing this gun and feeding system on a light duty Soyer or Nelson gun. It is the belief of Nelson Stud Welding Division's engineering staff that the additional mass and friction associated with the moving parts of the stud feeding mechanism would exceed the long term capabilities of the solenoid and lifting mechanism of any of these lighter duty gun designs.

D.1.4.3. In the interest of reliability, Nelson Stud Welding plans to continue the use of their standard duty lifting mechanism and solenoid.

D.1.5. Stud Loading

D.1.5.1. A plastic cap was designed and fabricated to protect the end of the spring plunger from contact with the ship surfaces as suggested by Newport News Shipbuilding.



NSRP #7-96-7 Final Report

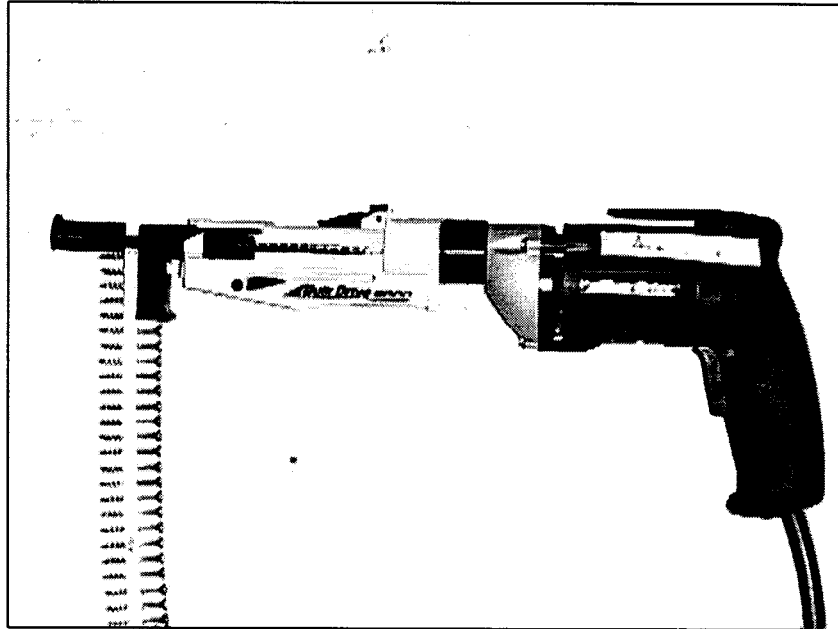
- D.1.5.2. Also as suggested by Newport News, the upper slider was redesigned for use with a shorter plastic handle for loading studs into the chuck. It was believed that this may help eliminate the feeding mechanism binding caused by the imparting of a twisting motion with the longer handle originally provided. It may also reduce or eliminate the possibility of the spring plunger breaking.



- D.1.5.3. No change was made in the choice of spring plunger which latches the mechanism in the forward position while welding. The use of an inexpensive commonly available component minimizes its cost of replacement.
- D.1.5.4. Bath Iron Works proposed that a feeding mechanism requiring the use of only one hand be developed. During the development of specifications for this project, Nelson Stud Welding Division explored several alternate methods of stud loading. Many of these were rejected as being impractical or requiring utilities which may not be available at all shipyards. Some of these included:
- D.1.5.4.1. The use of compressed air and a gun mounted cylinder for stud loading was considered. This would have been very close to the design used for Nelson's existing field proven automatic feed stud welders. Unfortunately, the survey of shipyards taken at the inception of this project indicated that only a small minority had compressed air consistently available for operation of such a stud loading device.

NSRP #7-96-7 Final Report

D.1.5.4.2. A single handed mechanism that telescopes upon itself like the automatic screw gun shown was considered. It was determined that such a mechanism is practical only where all motions required during operation are in a single direction. A device that provides forward motion to load the stud to the chuck, an opposite motion to pull the stud away from the work surface, and a subsequent forward motion to plunge the stud into the molten pool of metal was determined to be so complex as to be unreliable in service.



D.1.5.4.3. Based on these and other considerations described in the Milestone #3 document "*Report on Equipment Specifications*" Nelson Stud Welding developed a fully mechanical, operator driven stud loading device.

D.1.6. Stud Supply Magazine

D.1.6.1. Other potentially improved approaches to the stud supply magazine were explored. These took into consideration the difficulty of dealing with small fasteners in a shipbuilding environment. Methods of keying, pinning, chamfering stud entry areas, and other improvements were also considered in the second iteration of this design. For specific changes see section D.5.1 Stud Size Changeover.

D.1.7. Bearings

D.1.7.1. Since no bearing issues arose during field testing, no changes were made in this area.

NSRP #7-96-7 Final Report

D.1.8. Spark Shield and Foot

D.1.8.1. The proposal holding the most promise for reduction of spatter buildup, simplicity in maintaining stud perpendicularity, and light weight was the open "horseshoe" foot suggested by Newport News Shipbuilding. The NNS design was adapted to fit the leg and chuck spacing of the standard Nelson stud welding gun.

D.1.9. Orientation

D.1.9.1. The only apparent orientation issues pertained to gun weight and weld spatter buildup. Measures to further reduce weight were pursued as indicated in D.1.2. Spatter buildup was addressed in accordance with D.1.8.1 above.

D.2. Welding Power Unit

D.2.1. Size and Weight -

Only positive comments were received regarding the size and weight of the prototype ArcLite™ power unit. Production models are of generally the same size and weight.

D.2.2. Stud Size Capacity -

The Nelson® ArcLite™ power unit fully met the duty cycle and stud size requirements of this field test. No corrective action is required for this item. See section C.2.2 for more information about other studs welded using the drawn arc process during field testing.

D.2.3. Controls -

The ArcLite™ welding power unit has potentiometers for time and current settings. A key switch is provided for selection of either the short cycle or drawn arc process. A two character seven segment LED display is provided for error message display.

D.2.3.1. Newport News suggested that a display of actual weld time and current be provided. In its current design with a two character readout, this feature is not practical. A significant redesign would have been required to provide enough characters for display of weld time and/or current. Such a redesign was not undertaken.

D.2.3.2. The production version of this power unit's control software has enhanced error detection with the display of numeric codes and a published list of error messages.

D.2.3.3. A protective cover for the front of the power unit was also recommended by Newport News. This would need to be examined on

NSRP #7-96-7 Final Report

a case by case basis. Different field applications may require a different method of covering part or all of the front surface of the power unit. In most cases, the front would be uncovered to facilitate adjustment of welding parameters. No action was taken on a protective covering.

D.2.4. Operating Voltage -

Production versions of the North American model of the ArcLite™ power unit are intended for operation on 480 volts with commercial line voltage tolerances not to exceed $\pm 10\%$. This eliminates the need for the special care in field testing that line voltages of less than 480 volts were used.

D.3. Insulation Pins

D.3.1. Length -

Newport News found some studs that were noticeably shorter than others in the same cartridge.

D.3.1.1. The studs for field testing were manufactured using prototype techniques. Production quantities will be cold headed. Maintaining consistent stud lengths will not be the problem in production that it was for prototype manufacture.

D.3.2. Diameter -

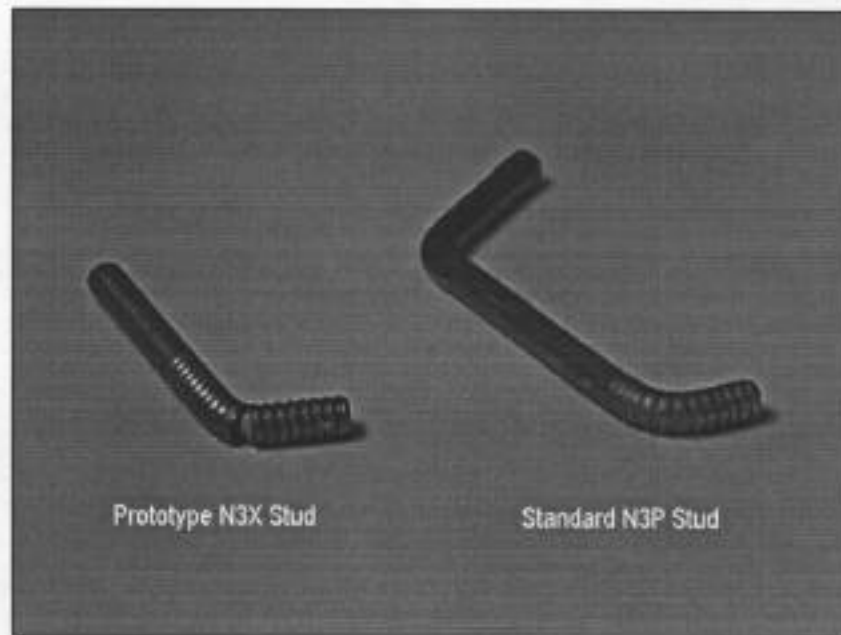
The diameter of the prototype studs as manufactured was in accordance with per MIL-S-24149 Type 6, Class 3, modified. No corrective action was required for this item.

D.3.3. Material -

The stud chemistry and minimum tensile strengths of the studs manufactured for field testing met the MIL specification requirements. Studs yielding through the root of the annular grooves when sharply bent prompted Bath Iron Works to suggest that all unnecessary annular rings be eliminated in production. Such a change might preclude automatic processes for filling the cartridges and would certainly require that they be placed into the magazine on the gun with a particular orientation.

NSRP #7-96-7 Final Report

D.3.3.1. Studs for field testing were manufactured using prototype techniques. The material used was C-1018 bar stock with an ultimate tensile strength of 103 ksi. This steel then experienced work hardening in the subsequent centerless grinding and thread rolling operations to approximately 122 ksi. Production studs of similar designs are normally cold formed from C-1010 mild steel wire and range from 55 to 70 ksi as manufactured. The prototype studs tended to break when bent using a hammer while similar production studs did not as shown in the photograph. This failure mode should not be an issue with production lots and their significantly lower ultimate tensile strengths.



D.3.4. Feeding Method

Disposable opaque extruded PVC cartridges preloaded with studs will be used for subsequent production as they were for the prototypes. However, a significant change in this area is that all exterior dimensions of the cartridges are now the same. This provides for the possibility of common shipping containers for all stud lengths in addition to the simplification it allows in changeover of the feeding system for other stud lengths.

D.3.5. Quantity -

Thirty studs per cartridge appeared to form a good compromise between cartridge and magazine lengths and frequency of reloading the gun. Pre-loaded stud cartridges are approximately 6" (150mm) long and can fit conveniently in a shirt pocket. The distance that the magazine extends below the gun to accommodate 30 studs places the end of the housing roughly even with the bottom surface of the gun handle. No change was made in this item.

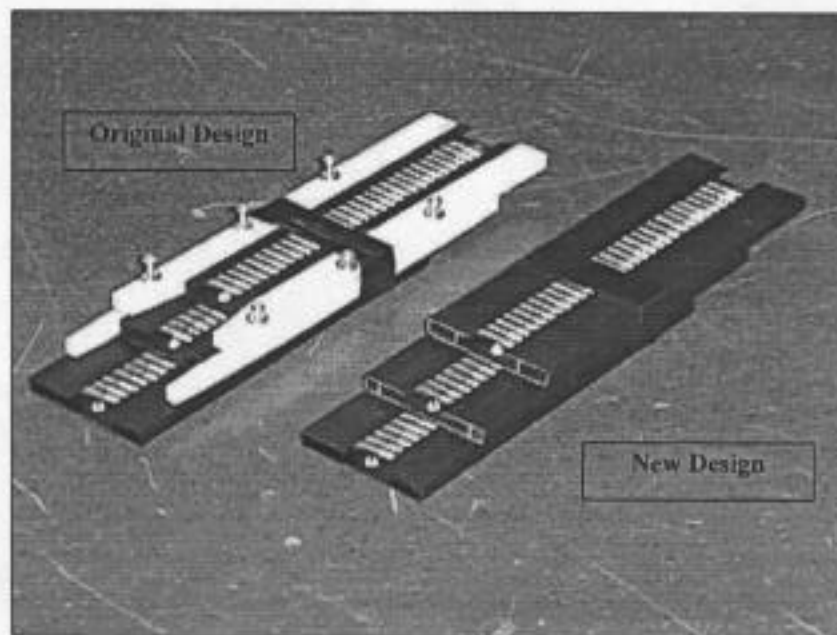
NSRP #7-96-7 Final Report

D.4. Gun Adjustment and Operation

D.4.1. Stud Size Changeover -

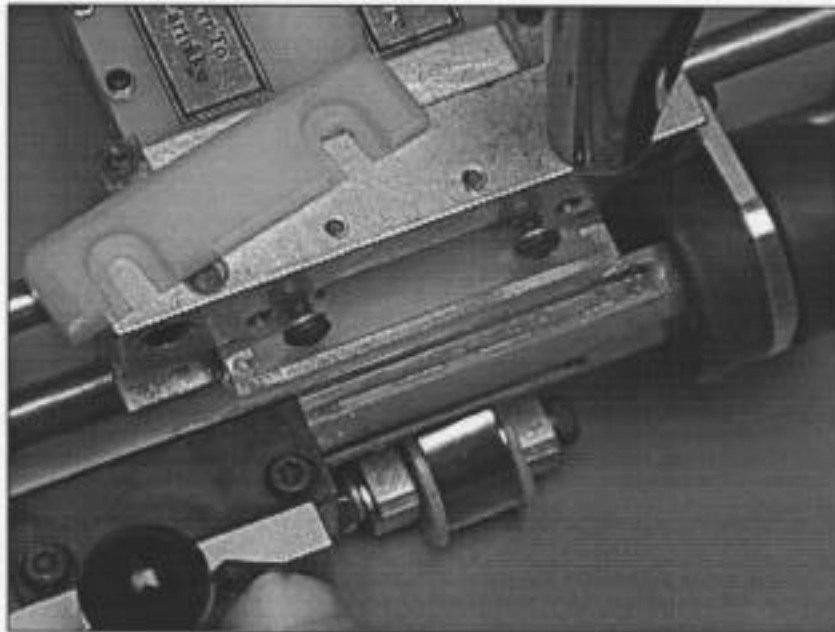
This is the issue that was of most concern in the field. Both Bath Iron Works and Newport News Shipbuilding made suggestions for improvements in this area.

- D.4.1.1. The cartridges for the .94" and 1.44" long studs were redesigned to have the same outside dimensions as those for 1.94" long studs. This eliminated the need for the nylon filler bars used to take up the excess space in the magazine housing. It also eliminated the small screws formerly used to retain these spacers in the magazine housing.

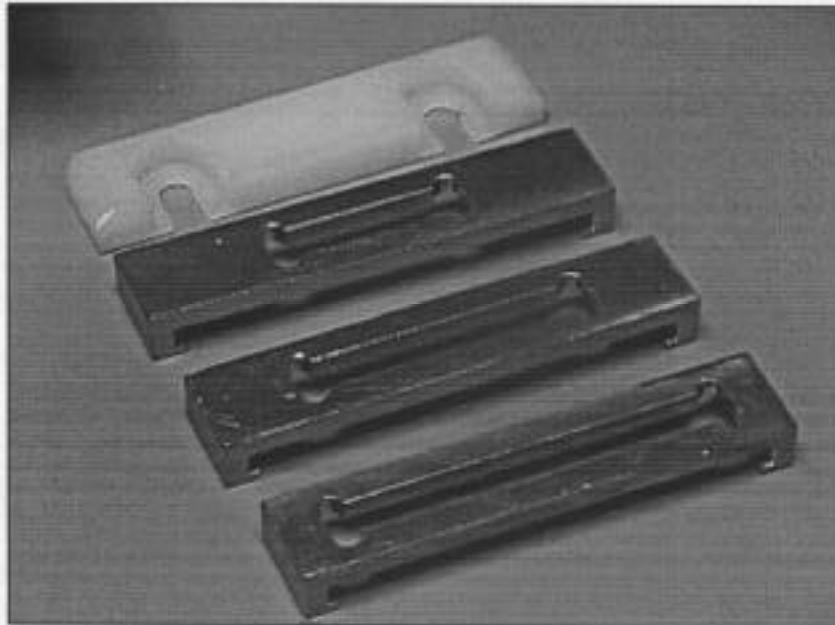


- D.4.1.2. The aperture plate and its retention method were redesigned to eliminate the need for removing screws when changing aperture plates as dictated by a change in stud length. This was accomplished by extending slots to the edge of a newly designed removable aperture plate keeper. It is only necessary to loosen the screws a turn or so to allow removing the aperture plate keeper and provide access to the aperture plate for removal.

NSRP #7-96-7 Final Report



D.4.1.3. The new aperture plates were designed to be the same width as the magazine housing assembly. This allows simply placing the aperture plate keepers tight against the sides of the magazine housing to ensure the proper location of the aperture plate on the magazine.



D.4.1.4. A chamfered funnel entry was incorporated in the chuck adaptor bottom opening to help guide studs into the feeding chamber of the gun. This significantly improved the ability of studs to negotiate this transition.

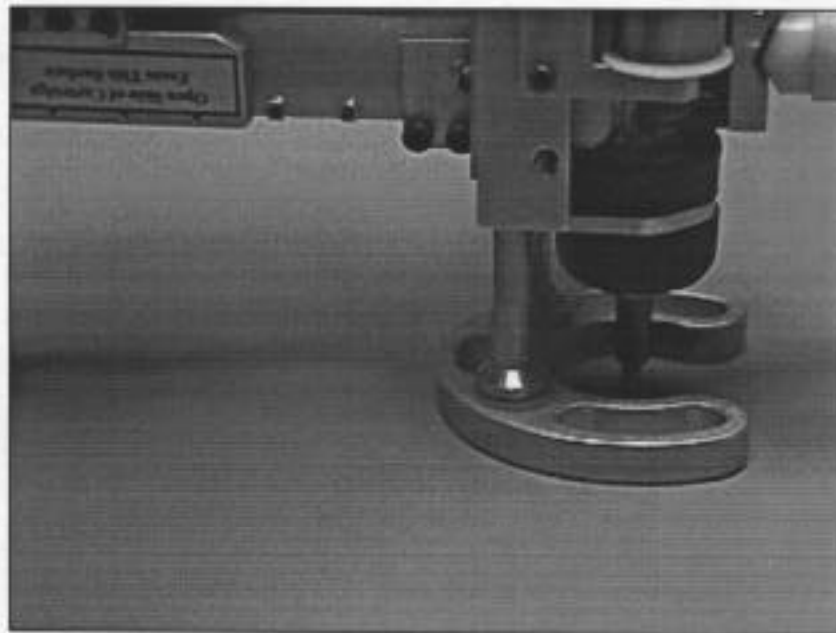
NSRP #7-96-7 Final Report

D.4.1.5. The ease of alignment of the new aperture plates with the magazine housing assembly and the addition of a chamfered opening in the bottom of the chuck adaptor precluded the need for the alignment aid and pinning suggested by two test sites and described at C.4.1.3 and C.4.1.4 above.

D.4.2. Welding -

Other than the stud feeding methodology, the welding tool of this project operates like any other hand held stud welding gun. Operation is natural and intuitive for any operator who has previously used stud welding equipment.

D.4.2.1. The change to an open sided foot plate as described in D.1.8.1 simplified maintaining stud perpendicularity and makes removal of the gun from a welded stud a smoother motion. This may also facilitate locating the gun using chalk marked grids on work surfaces.



D.4.2.2. Several sharp corners and edges were reduced or eliminated. These included those in the area of the aperture plate retainers which replaced the original aperture plate mounting arrangement and the front bearing mounting plate.

NSRP #7-96-7 Final Report

E. Appendix

E.1. Gun, Feeding System and Power Unit Instruction Manual

NOTE on N7-96-7:

The instruction manual will not be available until Nelson Stud Welding finalizes the product.

For more information about the
National Shipbuilding Research Program
please visit:

<http://www.nsrp.org/>

or

<http://www.USAShipbuilding.com/>